Steel Box Earth-Covered Magazine

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Overview

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- Purpose and Uses
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- Magazine Design
  - Vertical Loading
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Introduction

- Currently seeking formal approval for the design of a steel-box earth-covered magazine (ECM)
- Seeking incorporation into DDESB TP-15
- Passed review of U.S. Army Corps of Engineers as well as the U.S. Army Technical Center for Explosives Safety (USATCES)
- Seeking 3-bar headwall designation
Purpose and Uses

- Provide a cost-effective, expedited method to utilize reduced ECM criteria for explosives storage
- Other current ECM designs have significant drawbacks
  - Significant cost ($1M+ for an arch ECM and $3-5M for a box-type ECM)
  - Lengthy on-site construction
- The ARMAG pre-fabricated ECM solves these issues
  - Anticipated cost of $325,000 including concrete pad, delivery, and earthwork
  - On-site construction involves only a concrete pad and earthwork
- Acquisition can also potentially be simplified in that the ARMAG ECM may be able to be purchased using equipment funds, if applicable acquisition procedures allow
Purpose and Uses

- The ARMAG ECM provides an explosives storage option that can also alleviate limitations within existing storage facilities
  - In many locations, limited existing facilities are used to store Hazard Division (HD) 1.1 materials as well as less-restrictive HD 1.3 and 1.4 materials
  - Existing facilities can be prioritized to store the HD 1.1 materials if desired, whereas the ARMAG ECM is well-suited to store material from any HD
- Storage space for large munitions (e.g., containerized missiles) is usually at a premium at storage locations
  - When smaller palletized material also requires storage, it often is required to utilize space within limited magazines
  - The ARMAG ECM is ideal for storing palletized materials, alleviating critical space within larger magazines for larger munitions
Basis of Design

- Designed as a mid-level storage capacity magazine
- 3-bar headwall designation
- Design NEW limit of 50,000 lb HD 1.1
- Design loads obtained from DoD 6055.09-M
  - Flat roof design load
    - 108 psi
    - Calculated impulse of 700 psi-ms (duration of 13 ms)
  - 3-bar headwall loading
    - 43.5 psi
    - Calculated impulse of 416 psi-ms (duration of 19 ms)
Basis of Design

- Headwall is 5/8\textsuperscript{th} inch steel plate supported by various beam/column members
- The steel plate headwall is comparable to the large steel doors of currently approved ECM types

<table>
<thead>
<tr>
<th>Magazine</th>
<th>Headwall size</th>
<th>Door size</th>
<th>% Door (approximate)</th>
<th>Thickness of Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>33-15-74</td>
<td>25 ft x 14 ft (arched)</td>
<td>10 ft x 10 ft</td>
<td>33%</td>
<td>5/8\textsuperscript{th} inch</td>
</tr>
<tr>
<td>RC Box Type C</td>
<td>95 ft x 16 ft</td>
<td>(3) 26 ft x 12 ft</td>
<td>62%</td>
<td>13/16\textsuperscript{th} inch</td>
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<tr>
<td>RC Box Type D</td>
<td>159 ft x 16 ft</td>
<td>(5) 25 ft x 11 ft</td>
<td>54%</td>
<td>13/16\textsuperscript{th} inch</td>
</tr>
<tr>
<td>421-80-07 (MSM)</td>
<td>25 ft x 11 ft</td>
<td>24 ft x 10 ft</td>
<td>87%</td>
<td>3/8\textsuperscript{th} inch</td>
</tr>
</tbody>
</table>
Magazine Design
Magazine Design

- Box-shaped, 40 feet in length, 13.5 feet wide, and 9 feet tall
- Headwall plate and wing-walls extend above the ECM roof and to the sides to support the soil backfill
- Magazine door is a single-leaf design, 7 feet in width
- Lightning protection system and ventilation stacks
- For additional views and sections of the magazine, please refer to the ARMAG ECM drawings
Magazine Design

- The blast-resistant structural system has two focus areas:
  - Vertical roof load
  - Horizontal headwall load
- The magazine is designed in accordance with United Facilities Criteria (UFC) 3-340-02, “Structures to Resist the Effects of Accidental Explosions”
- Each beam or column component is welded to an adjacent steel plate in 6-inch intervals along the length of the member, though the added flexural capacity is conservatively neglected
- Connections are designed to be simple bearing connections wherever possible to avoid moment transfer
- Rebound loads for all elements and connections are considered
Vertical Loading

- Blast loading of 108 psi
- Additional loads totaling 519 lb/ft$^2$:
  - Dead load of 2.5 ft of wet soil (456 lb/ft$^2$)
  - Combined live and snow load (63 lb/ft$^2$)
- Dynamic analyses for the vertical loads consider two scenarios:
  - Maximum dead load of 519 lb/ft$^2$
  - Minimum dead load of 240 lb/ft$^2$ (2 ft of dry soil in order to minimize the dynamic effect of the soil)
- Shear loads were verified for all cases
- Dynamic analysis shows that the worst-case scenario for deflection is the minimum dead load
Vertical Loading

1. Load bears on 3/8\textsuperscript{th} inch steel roof plate (not shown)
2. Transfers to W6x20 roof beam (24 inch on center)
3. Bears on W6x12 sidewall column; minimum moment transfer between roof beam and sidewall column
Horizontal Loading - Door

1. Load bears on 5/8\textsuperscript{th} inch steel door plate (not shown)
2. Transfers to W6x12 door beams
3. Bears on W12x35 door frame column
4. Bears on longitudinal hollow structural steel (HSS) 8x8x3/8 roof & floor beams
Horizontal Loading - Headwall

1. Load bears on 5/8\textsuperscript{th} inch steel headwall plate (not shown)
2. Transfers to W12x35 door frame column and W6x16 headwall column
3. Bears on longitudinal HSS 8x8x3/8 and HSS 8x4x1/4 roof & floor beams
Horizontal Loading – Longitudinal Beams

- Specially designed steel HSS compression members running the 40-foot length of the magazine roof and floor
  - Welded to the magazine roof providing a path for the headwall loads to transition into the structure over the entire length
  - Connection is a simple pinned/bearing connection
  - Ensures that the roof acts as a one-way transverse element
Conclusions

- The ARMAG ECM provides a convenient, cost-effective option for storage of practical quantities of explosives articles utilizing reduced separation criteria for ECM structures.
- The design of the ARMAG ECM meets and exceeds UFC 3-340-02 requirements.
- Additional details will be available as the design progresses through the DoD review process.
- Contact ARMAG for additional details.
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